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# ***SmartFusion Modbus TCP Demo Using lwIP and FreeRTOS***

***User's Guide***



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# Introduction

The SmartFusion<sup>®</sup> customizable system-on-chip (cSoC) integrates FPGA technology with the hardened ARM<sup>®</sup> Cortex<sup>™</sup>-M3 processor based microcontroller subsystem (MSS) and programmable high-performance analog blocks built on a low power flash semiconductor process. The MSS consists of hardened blocks, such as a 100 MHz ARM Cortex-M3 processor, peripheral DMA (PDMA), embedded nonvolatile memory (eNVM), embedded SRAM (eSRAM), embedded FlashROM (eFROM), external memory controller (EMC), watchdog timer, the Philips Inter-Integrated Circuit (I<sup>2</sup>C), serial peripheral interface (SPI), 10/100 Ethernet controller, real-time counter (RTC), general purpose input/output (GPIO) block, fabric interface controller (FIC), in-application programming (IAP), and system registers. The programmable analog block contains the analog compute engine (ACE) and analog front-end (AFE), consisting of analog-to-digital converters (ADCs), DACs, active bipolar prescalers (ABPS), comparators, current monitors, and temperature monitors.

The ethernet media access control (MAC) in a SmartFusion cSoC is a high-speed MAC ethernet controller with the following features:

- Carrier sense multiple access with collision detection (CSMA/CD) algorithms defined by the IEEE 802.3 standard
- Complies with the low-pin-count reduced media independent interface (RMII<sup>™</sup>) specifications
- Built in DMA controller to move data between external RAM and TX/RX FIFOs

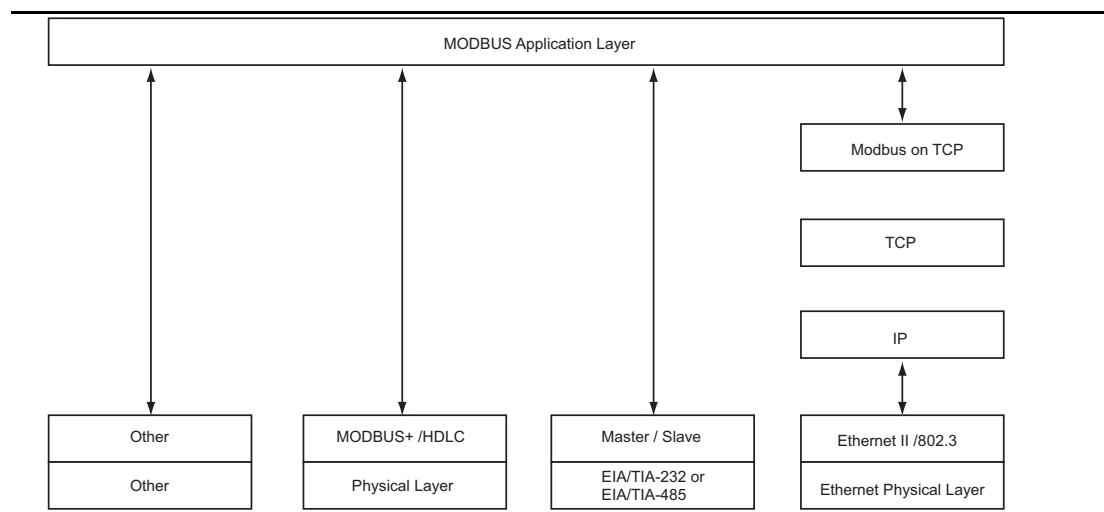
Refer to the [SmartFusion Microcontroller Subsystem User's Guide](#) for more details on the 10/100 Ethernet MAC interface. This user guide explains how to run the demo design running the Modbus TCP server ([www.freemodbus.org](http://www.freemodbus.org)) on the SmartFusion cSoC.

Modbus is an application layer messaging protocol, positioned at level 7 of the OSI model. It provides client/server communication between the devices connected on different types of buses or networks. It is a confirmed service protocol and offers many services specified by function codes. The Modbus function codes are elements of Modbus Request/Reply Protocol Data Units.

Modbus is an application layer messaging protocol for client/server communication between the devices connected on different types of buses or networks. It is currently implemented using:

- TCP/IP over ethernet
- Asynchronous serial transmission over a variety of media (wire: EIA/TIA-232-E, EIA-422, EIA/TIA-485-A; fiber, radio, etc.)
- Modbus PLUS, a high speed token passing network

Figure 1 illustrates the Modbus communication stack.



**Figure 1 • Modbus Communication Stack**

The complete specification for Modbus is available at [www.modbus.org](http://www.modbus.org).

The Modbus TCP implementation guidelines can be found in the [\*Modbus Messaging on TCP/IP Implementation Guide v1.0b\*](#).

The source code used for the design example in this document is from [www.freemodbus.org](http://www.freemodbus.org), with updates for the complete set of features of the Modbus layer.

This demo is designed for the [SmartFusion Development Kit Board](#) (A2F500-DEV-KIT) using lwIP and FreeRTOS. To familiarize yourself with the Microsemi SoC Products Group's tool chain and design flow, refer to the SmartFusion cSoC tutorials on [www.microsemi.com/soc/products/smartfusion/docs.aspx#tutorial](http://www.microsemi.com/soc/products/smartfusion/docs.aspx#tutorial).

# 1 – Reference Design Features

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The following versions of the stack are used for this demo.

1. lwIP TCP/IP stack version 1.3.2 ([www.sics.se/~adam/lwip/](http://www.sics.se/~adam/lwip/))
2. Modbus TCP server version 1.5 ([www.freemodbus.org](http://www.freemodbus.org)) with enhancements for the complete function code support as Modbus TCP server
3. FreeRTOS ([www.freertos.org](http://www.freertos.org))

## Supported Modbus Function

Based on the Free MODBUS communications stack, the reference design supports the following Modbus functions out of the box. This design example supports all the function code required for the Modbus slave. These function codes are verified with the Modbus conformance test tool from [www.modbus.org](http://www.modbus.org).

- Read Input Registers (function code 0x04)
- Read Holding Registers (function code 0x03)
- Write Single Registers (function code 0x06)
- Write Multiple Registers (function code 0x10)
- Read/Write Multiple Registers (function code 0x17)
- Read Coils (function code 0x01)
- Write Single Coils (function code 0x05)
- Write Multiple Coils (function code 0x0F)
- Read Discrete Inputs (function code (0x02)

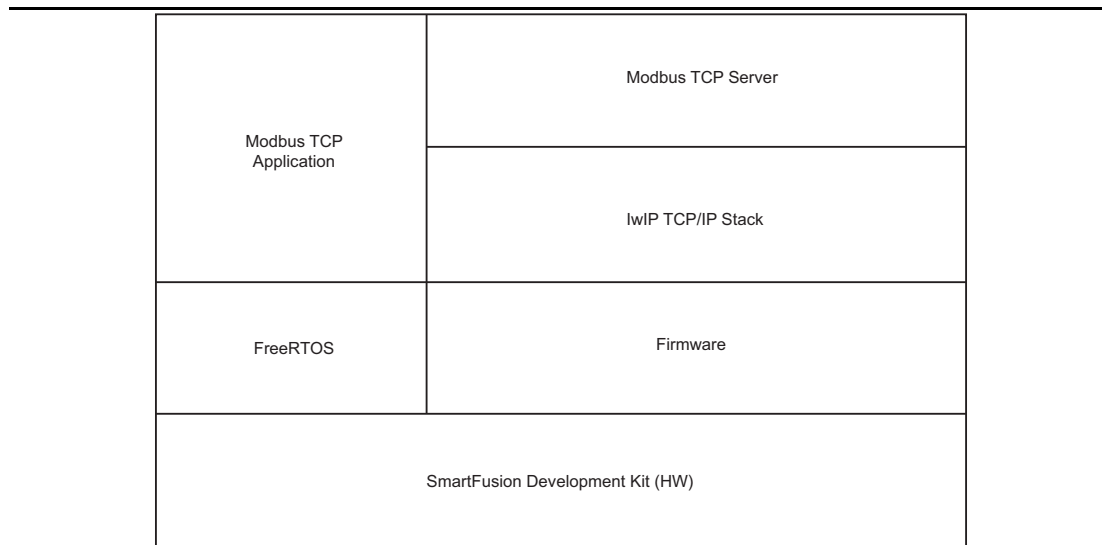


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## 2 – Modbus TCP Server on SmartFusion cSoC

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Figure 2-1 shows the block diagram of the software stacks used in this demo design.



**Figure 2-1 • Block Diagram of MODBUS TCP Server and Application on SmartFusion**

This demo design describes the Modbus TCP Server running on the SmartFusion Development Kit Board and responding to the Modbus TCP client running on the development PC. The following function codes are demonstrated on SmartFusion:

- Read discrete inputs (fn code 02) for mapped global data
- Read holding registers (fn code 03) for mapped global data
- Read input register (fn code 04) for ACE current reading
- Write multiple coils (fn code 15) for toggling the LEDs using GPIOs





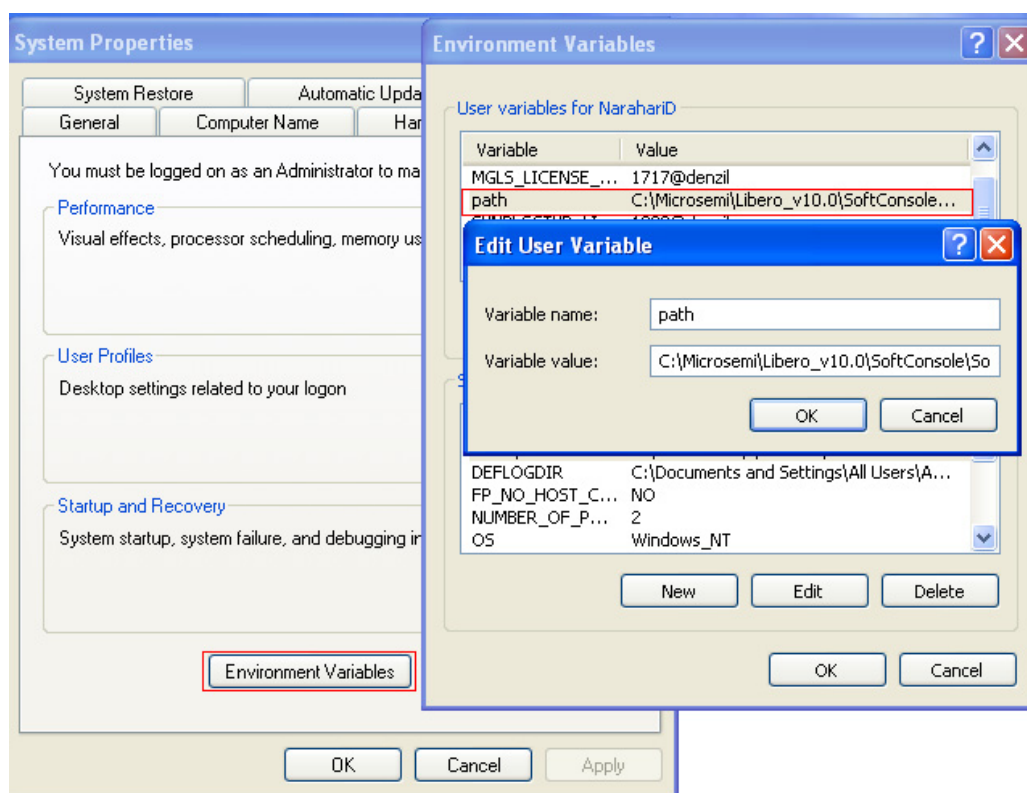
## 3 – Modbus TCP Demo Requirement

The *SmartFusion Development Kit Board* (A2F500-DEV-KIT) is issued to run the demo design. As this demo is using the various software stacks, it is very difficult to keep them running from the internal memories of the SmartFusion. Therefore, this demo is made to run from the external memories of the *SmartFusion Development Kit Board*. Table 3-1 gives the jumper settings for the development kit to access the external memories.

**Table 3-1 • Jumper Settings for Accessing the External Flash and RAM**

Jumper	Pin	Pin
JP17	2	3
JP19	2	3
JP24	1	2
JP16	2	3

For additional information on the board, refer to the *SmartFusion Development Kit User's Guide*. Add the SoftConsole installation path to the Environment Variables; for example, C:\Program Files\Actel\SoftConsole v3.2\Sourcery-G++\bin. This is required by the host tools to create the \*.bin file of the executable from \*.elf. Figure 3-1 shows the Path settings in the Environment Variables window.



**Figure 3-1 • Path Settings in Environment Variables**



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## 4 – Running the Design

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Download the design files from the Microsemi SoC Products Group website:  
[www.microsemi.com/soc/download/rsc/?f=A2F\\_Modbus\\_TCP\\_Ref\\_Design\\_DF](http://www.microsemi.com/soc/download/rsc/?f=A2F_Modbus_TCP_Ref_Design_DF).

The zipped folder for this demo design contains the following components shown in Figure 4-1.

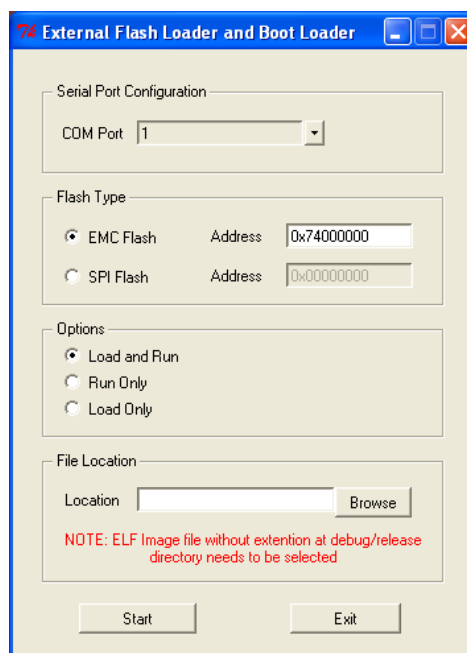


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**Figure 4-1 • Demo Directory Structure**

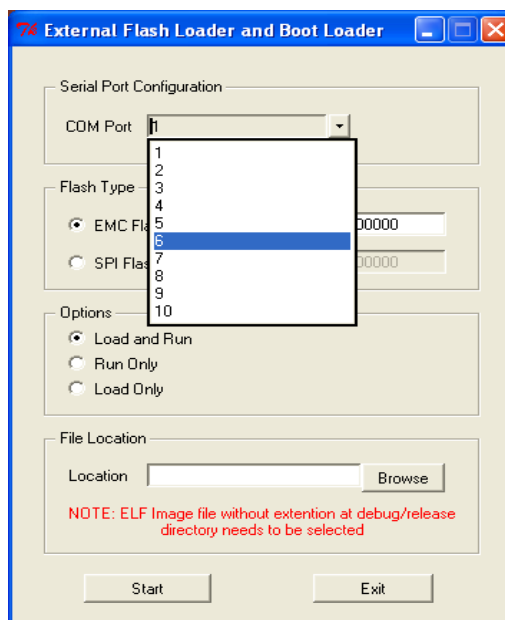
1. **A2F500:** This folder consists of the Libero Verilog project for the A2F500 based SmartFusion Development Kit Board. These project files do not work with the A2F200 based SmartFusion Evaluation Kit Board.  
  
The SoftConsole folder in the above directories contains a Software folder consisting of SoftConsole projects for running the Modbus TCP/IP Server on the lwIP\_1\_3\_2 stack on SmartFusion and the External Flash Loader for loading images to external flash on SmartFusion Kits.  
  
This software works with A2F500 based SmartFusion Development Kit Board.
2. **Host Tool and HostTool\_ModbusClient:** From the remote host, these tools are used to run this demo.
3. **Release\_Images:** This folder contains the GUI interface to load the Images to external flash and execute the images from external flash. Debugging is not possible with this method. The remainder of this section explains how to use the prebuild image that accompanies this demo.

4. Using the pre-build release images:
  - Connect the Ethernet cable and UART cable to the A2F500 Development Kit.
  - Program the top\_level\_modbus\_tcp\_server\_A2F500.pdb using FlashPro.
  - Double-click the External Flash loader GUI tool (SmartFusion\_Flash\_Loader\_V1.0.exe). This displays the GUI for running the Modbus TCP demo (Figure 4-2).



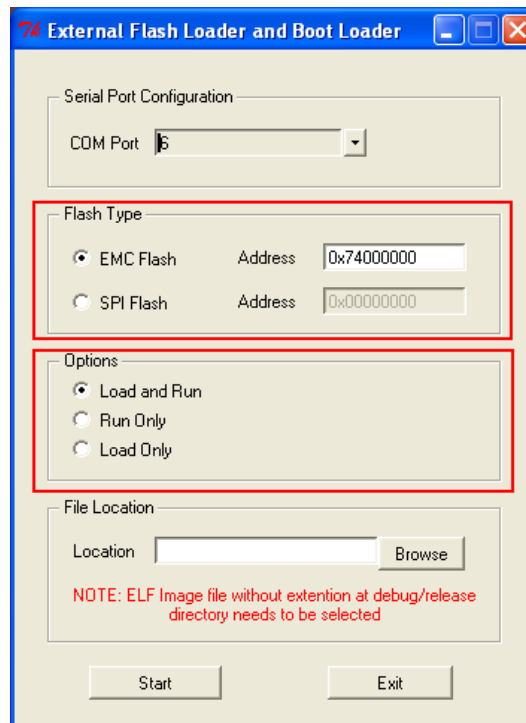
**Figure 4-2 • GUI for Running the Modbus TCP Demo**

5. From the drop-down list (Figure 4-3), select a COM port to which the A2F500-DEV-KIT is connected.



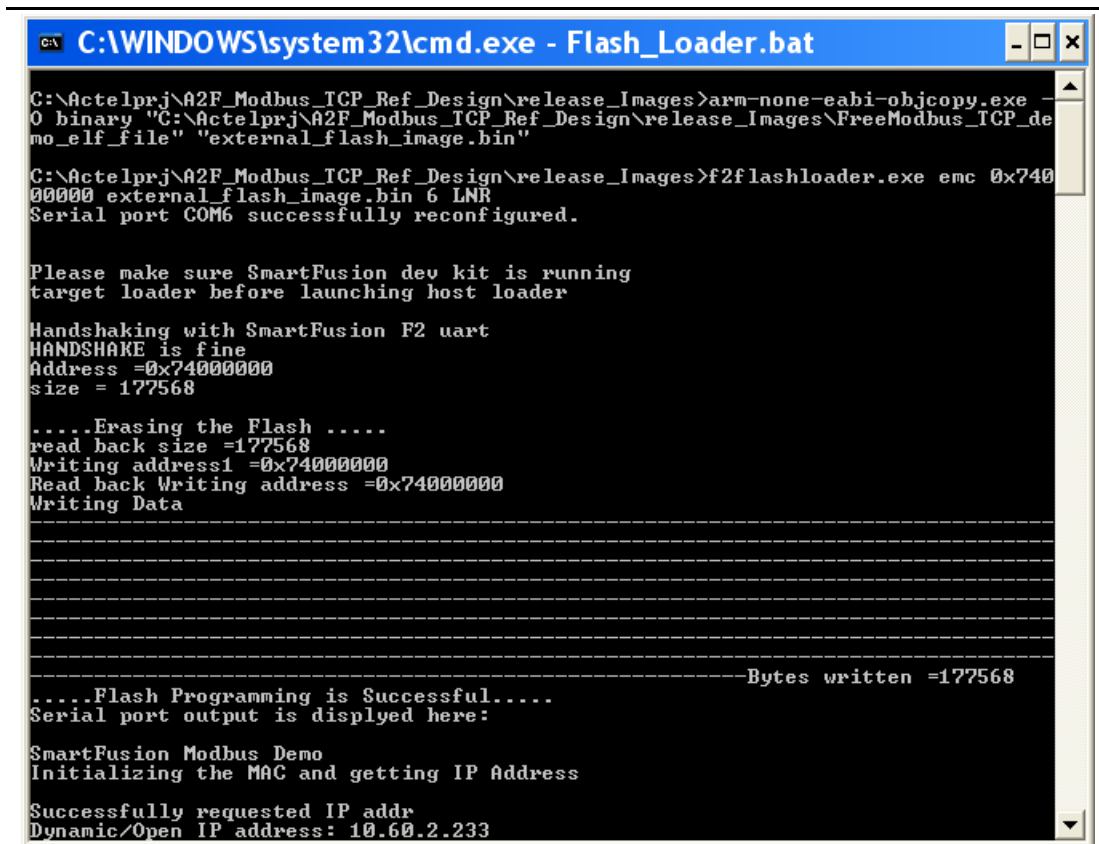
**Figure 4-3 • COM Port Selection**

Select **EMC Flash** for Flash Type and **Load and Run** for Options (Figure 4-4). These are the default settings for the TCP demo.



**Figure 4-4 • Default Settings for MODBUS TCP Demo**

- Browse for the \*.elf file (FreeModbus\_TCP\_demo\_elf\_file) that is provided in the release\_Images folder, then click **Start**. The Command Prompt window is displayed (Figure 4-5). This programs the external flash with the Modbus demo image and starts the demo.



```

C:\> C:\WINDOWS\system32\cmd.exe - Flash_Loader.bat

C:\Actelprj\A2F_Modbus_TCP_Ref_Design\release_Images>arm-none-eabi-objcopy.exe -O binary "C:\Actelprj\A2F_Modbus_TCP_Ref_Design\release_Images\FreeModbus_TCP_demo_elf_file" "external_flash_image.bin"

C:\Actelprj\A2F_Modbus_TCP_Ref_Design\release_Images>f2flashloader.exe emc 0x74000000 external_flash_image.bin 6 LNR
Serial port COM6 successfully reconfigured.

Please make sure SmartFusion dev kit is running
target loader before launching host loader

Handshaking with SmartFusion F2 uart
HANDSHAKE is fine
Address =0x74000000
size = 177568

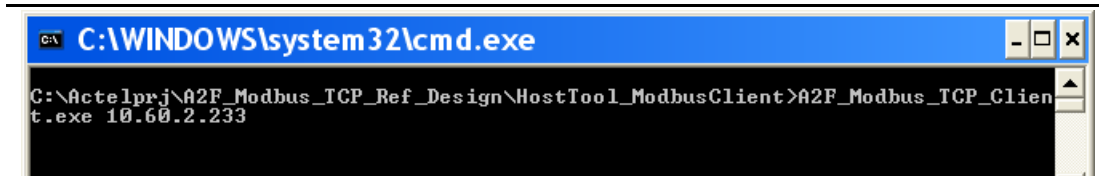
.....Erasing the Flash .....
read back size =177568
Writing address1 =0x74000000
Read back Writing address =0x74000000
Writing Data
-----
-----Bytes written =177568
.....Flash Programming is Successful.....
Serial port output is displayed here:

SmartFusion Modbus Demo
Initializing the MAC and getting IP Address

Successfully requested IP addr
Dynamic/Open IP address: 10.60.2.233
  
```

**Figure 4-5 • EMC Flash Programming and Running MODBUS TCP Demo**

- Open a new command prompt and type the command shown in Figure 4-6 (run the Modbus client, A2F\_Modbus\_TCP\_Client.exe, with the IP address displayed in the above step as input):  
A2F\_Modbus\_TCP\_Client.exe 10.60.2.233.



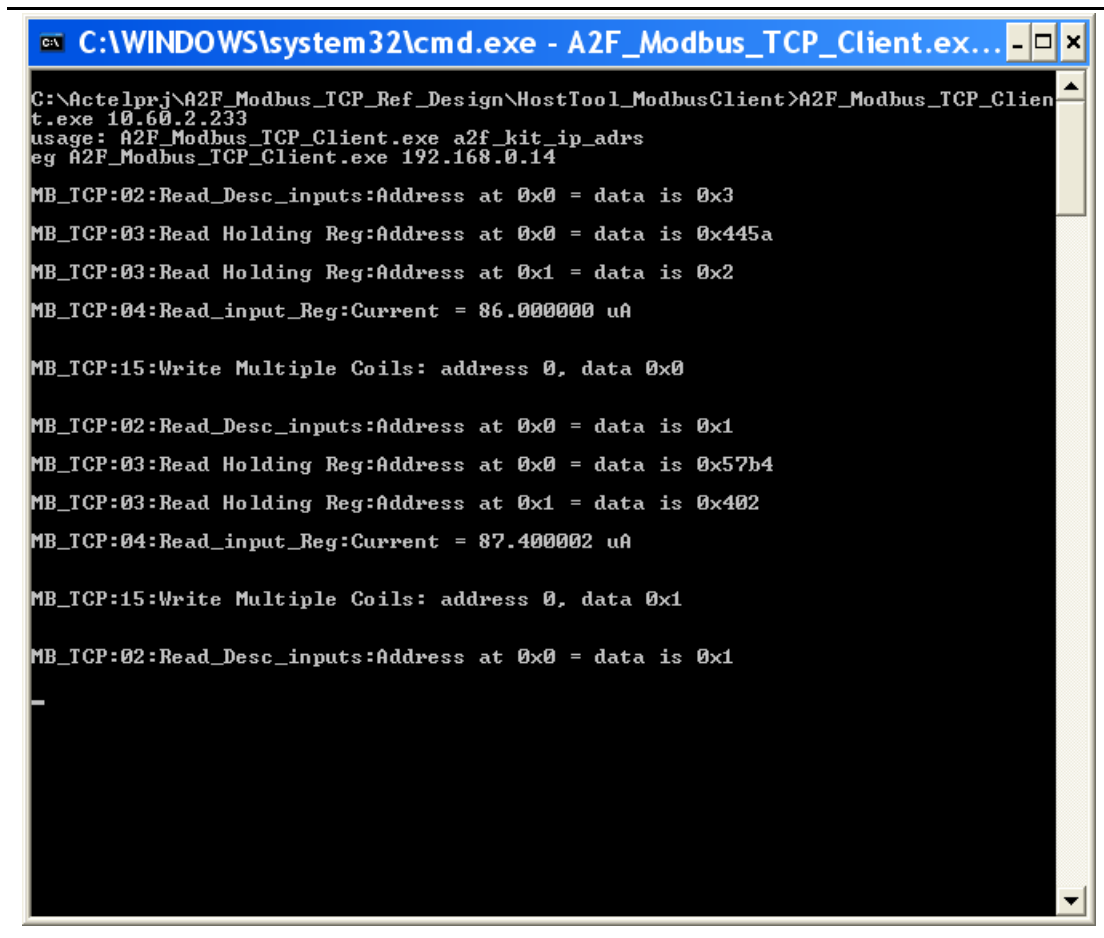
```

C:\> C:\WINDOWS\system32\cmd.exe

C:\Actelprj\A2F_Modbus_TCP_Ref_Design\HostTool_ModbusClient>A2F_Modbus_TCP_Client.exe 10.60.2.233
  
```

**Figure 4-6 • Running the Modbus Client**

Figure 4-7 shows the current monitor values.



```

C:\Actelprj\A2F_Modbus_TCP_Ref_Design\HostTool_ModbusClient>A2F_Modbus_TCP_Client.exe 10.60.2.233
usage: A2F_Modbus_TCP_Client.exe a2f_kit_ip_addr
eg A2F_Modbus_TCP_Client.exe 192.168.0.14

MB_TCP:02:Read_Desc_inputs:Address at 0x0 = data is 0x3
MB_TCP:03:Read Holding Reg:Address at 0x0 = data is 0x445a
MB_TCP:03:Read Holding Reg:Address at 0x1 = data is 0x2
MB_TCP:04:Read_input_Reg:Current = 86.000000 uA

MB_TCP:15:Write Multiple Coils: address 0, data 0x0

MB_TCP:02:Read_Desc_inputs:Address at 0x0 = data is 0x1
MB_TCP:03:Read Holding Reg:Address at 0x0 = data is 0x57b4
MB_TCP:03:Read Holding Reg:Address at 0x1 = data is 0x402
MB_TCP:04:Read_input_Reg:Current = 87.400002 uA

MB_TCP:15:Write Multiple Coils: address 0, data 0x1

MB_TCP:02:Read_Desc_inputs:Address at 0x0 = data is 0x1

```

**Figure 4-7 • Current Monitor Values**

8. This demo shows the Modbus TCP functions for:
  - Reading the discrete inputs (fn code 02) for a mapped global data
  - Reading the holding register (fn code 03) for mapped global data
  - Reading the input register (fn code 04) for ACE current reading
  - Writing multiple coils (fn code 15) for toggling the LEDs using GPIOs. The corresponding LED goes off as the data value shown for function 15 in [Figure 4-7](#).
9. Vary the POT values on the A2F500-DEV-KIT. The current changes are reflected in the command prompt window ([Figure 4-7](#)).
10. Once the test has been done, close the command prompts. This is required to close the COM port opened by the tools.

## Debug Mode

Refer to the [Using UART with a SmartFusion cSoC Libero SoC and SoftConsole Flow Tutorial](#) to understand the flow for debugging mode.





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## 5 – References

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The following references were used in this document:

1. Microsemi SoC Products Group System Solutions home page:  
[www.microsemi.com/soc/products/solutions/default.aspx](http://www.microsemi.com/soc/products/solutions/default.aspx)
2. Microsemi SmartFusion cSoC home page:  
[www.microsemi.com/soc/products/smartfusion/default.aspx](http://www.microsemi.com/soc/products/smartfusion/default.aspx)
3. The Modbus Organization home page: [www.modbus.org](http://www.modbus.org)
  - FAQ: [www.modbus.org/faq.php](http://www.modbus.org/faq.php)
  - Technical resources including specifications and links to free and commercial Modbus tools and resources: [www.modbus.org/tech.php](http://www.modbus.org/tech.php)
4. Wikipedia page on Modbus: <http://en.wikipedia.org/wiki/Modbus>
5. FreeModbus home page: [www.freemodbus.berlios.de/](http://www.freemodbus.berlios.de/)
  - API Documentation: [www.freemodbus.berlios.de/api/index.html](http://www.freemodbus.berlios.de/api/index.html)
  - Examples using Modpoll: [www.freemodbus.berlios.de/index.php?id=1](http://www.freemodbus.berlios.de/index.php?id=1)
6. Selected suggested Modbus master tools for testing and exercising the reference design:
  - proconX Pty Ltd Modpoll<sup>®</sup> – a freeware ([www.modbusdriver.com/info/LICENSE-FREE](http://www.modbusdriver.com/info/LICENSE-FREE)) PC hosted command line read-only Modbus master: [www.modbusdriver.com/modpoll.html](http://www.modbusdriver.com/modpoll.html)
  - Automated Solutions Inc Modbus RTU/ASCII Master ActiveX Control and example programs: [www.automatedsolutions.com/demos/#MBACTIVEX](http://www.automatedsolutions.com/demos/#MBACTIVEX). You can download a 30 day trial demo version from Automated Solutions Inc: [www.automatedsolutions.com/products/modbusrtu.asp](http://www.automatedsolutions.com/products/modbusrtu.asp).
7. Modbus tutorials and overviews:
  - Automation.com<sup>™</sup> introduction to the Modbus protocol: [www.automation.com/resources-tools/articles-white-papers/fieldbus-serial-bus-io-networks/introduction-to-modbus](http://www.automation.com/resources-tools/articles-white-papers/fieldbus-serial-bus-io-networks/introduction-to-modbus)
  - National Instruments<sup>™</sup> introduction to the Modbus protocol: [www.zone.ni.com/devzone/cda/tut/p/id/7675](http://www.zone.ni.com/devzone/cda/tut/p/id/7675)
  - AutomatedBuildings.com introduction to the Modbus protocol:
    - Part 1: [www.automatedbuildings.com/news/sep08/articles/cctrls/080819014909cctrls.htm](http://www.automatedbuildings.com/news/sep08/articles/cctrls/080819014909cctrls.htm)
    - Part 2: [www.automatedbuildings.com/news/dec08/articles/cctrls/081124120101cctrls.htm](http://www.automatedbuildings.com/news/dec08/articles/cctrls/081124120101cctrls.htm)
8. lwIP TCP/IP stack: [www.sics.se/~adam/lwip/](http://www.sics.se/~adam/lwip/)
9. FreeRTOS stack: [www.freertos.org](http://www.freertos.org)



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## List of Changes

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The following table lists critical changes that were made in each revision of the chapter.

Date	Changes	Page
50200286-2/05.12	Replaced <a href="#">Figure 4-1</a> (SAR 38390)	11
	Modified the " <a href="#">Running the Design</a> " section (SAR 38390)	11
50200286-1/02.12	The <a href="#">Figure 4-1</a> was updated.	11
	The " <a href="#">Running the Design</a> " section was revised.	11

*Note:* \*The part number is located on the last page of the document. The digits following the slash indicate the month and year of publication.



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## A – Product Support

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Microsemi SoC Products Group backs its products with various support services, including Customer Service, Customer Technical Support Center, a website, electronic mail, and worldwide sales offices. This appendix contains information about contacting Microsemi SoC Products Group and using these support services.

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From North America, call 800.262.1060

From the rest of the world, call 650.318.4460

Fax, from anywhere in the world, 650.318.8044

### Customer Technical Support Center

Microsemi SoC Products Group staffs its Customer Technical Support Center with highly skilled engineers who can help answer your hardware, software, and design questions about Microsemi SoC Products. The Customer Technical Support Center spends a great deal of time creating application notes, answers to common design cycle questions, documentation of known issues, and various FAQs. So, before you contact us, please visit our online resources. It is very likely we have already answered your questions.

### Technical Support

Visit the Customer Support website ([www.microsemi.com/soc/support/search/default.aspx](http://www.microsemi.com/soc/support/search/default.aspx)) for more information and support. Many answers available on the searchable web resource include diagrams, illustrations, and links to other resources on the website.

### Website

You can browse a variety of technical and non-technical information on the SoC home page, at [www.microsemi.com/soc](http://www.microsemi.com/soc).

### Contacting the Customer Technical Support Center

Highly skilled engineers staff the Technical Support Center. The Technical Support Center can be contacted by email or through the Microsemi SoC Products Group website.

#### Email

You can communicate your technical questions to our email address and receive answers back by email, fax, or phone. Also, if you have design problems, you can email your design files to receive assistance. We constantly monitor the email account throughout the day. When sending your request to us, please be sure to include your full name, company name, and your contact information for efficient processing of your request.

The technical support email address is [soc\\_tech@microsemi.com](mailto:soc_tech@microsemi.com).

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Microsemi SoC Products Group customers may submit and track technical cases online by going to [My Cases](#).

## Outside the U.S.

Customers needing assistance outside the US time zones can either contact technical support via email ([soc\\_tech@microsemi.com](mailto:soc_tech@microsemi.com)) or contact a local sales office. [Sales office listings](#) can be found at [www.microsemi.com/soc/company/contact/default.aspx](http://www.microsemi.com/soc/company/contact/default.aspx).

## ITAR Technical Support

For technical support on RH and RT FPGAs that are regulated by International Traffic in Arms Regulations (ITAR), contact us via [soc\\_tech\\_itar@microsemi.com](mailto:soc_tech_itar@microsemi.com). Alternatively, within [My Cases](#), select **Yes** in the ITAR drop-down list. For a complete list of ITAR-regulated Microsemi FPGAs, visit the [ITAR](#) web page.

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